

# LCRD Update and Path to Optical Relay Operations

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Exploration & **SPACE**  
Communications

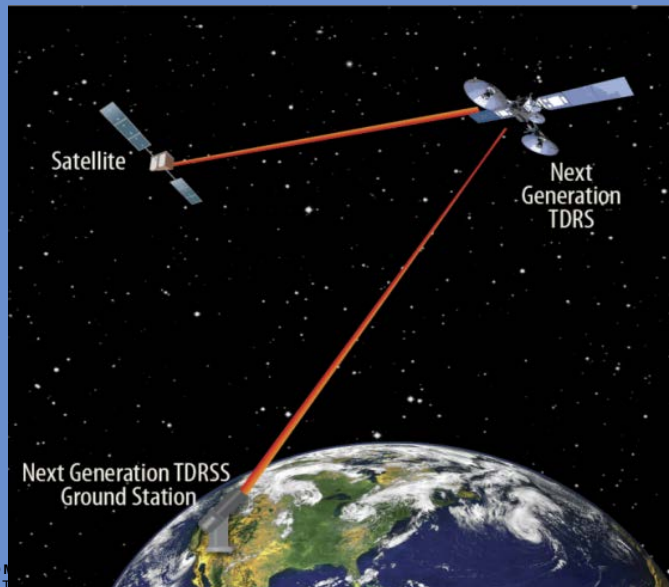
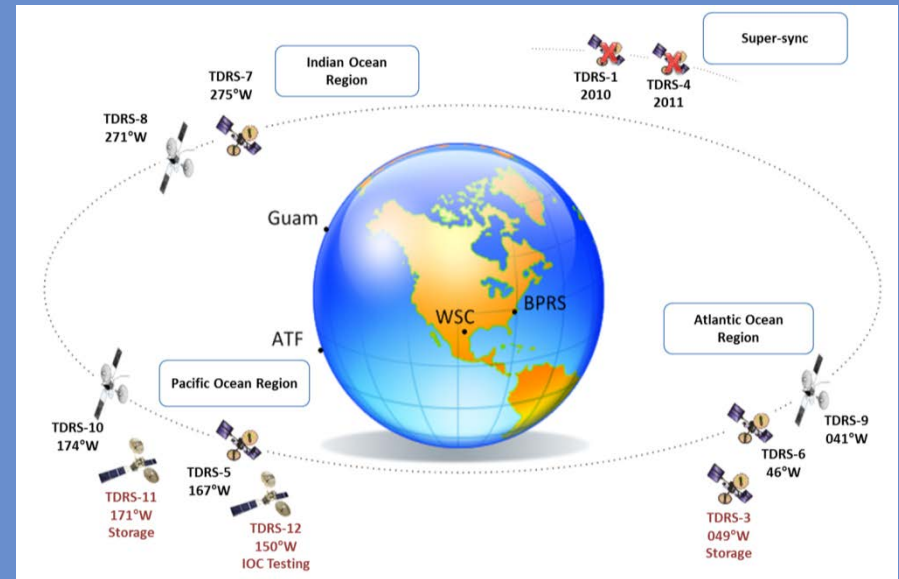
*More than you ever imagined...*



# Introduction



The NASA Space Network (or Tracking and Data Relay Satellite System) is comprised of a constellation of Tracking and Data Relay Satellites (TDRS) in geosynchronous orbit along with a network of associated ground stations and operation centers.



NASA is targeting a next generation of relay capability on orbit in the 2025 timeframe.



# LCRD Overview



## Demo Description

A minimum two-year flight demonstration (goal of five years) to advance optical communications technology toward infusion into deep space and near-Earth operational systems, while growing the capabilities of industry sources

## Objectives

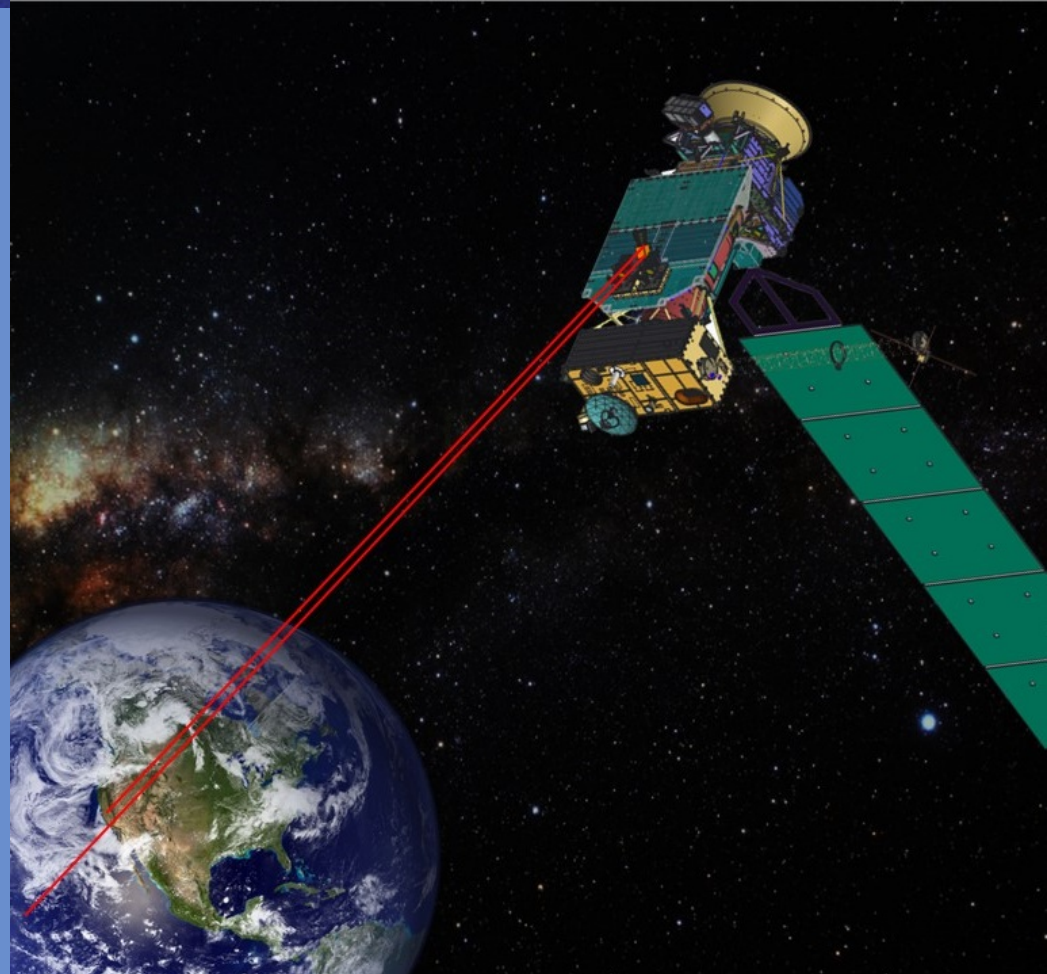
- Demonstrate bidirectional optical communications between geosynchronous Earth orbit (GEO) and Earth
- Measure and characterize the system performance over a variety of conditions
- Develop operational procedures and assess applicability for future missions
- Provide an on-orbit capability for test and demonstration of standards for optical relay communications

## Anticipated Benefits

- A reliable, capable and cost-effective optical communications technology for infusion into future operational systems

## Anticipated NASA Mission Use

- Next Generation Earth Relay
- Deep space and near-Earth science
- ISS and human spaceflight



# LCRD Mission Architecture



## LCRD Flight Payload

- 2 optical relay terminals
  - 10.8 cm aperture
  - 0.5 W transmitter
  - DPSK and PPM
- Space Switching Unit
- High data rate RF

## Optical Relay Link Features

- 2880 Mbps Uncoded DPSK
- 1244 Mbps Coded DPSK
- 311 Mbps 16-PPM
- Coding/Interleaving at link edges
  - Rate  $\frac{1}{2}$  DVB-S2 codec (LDPC)
  - 1 second of interleaving for atmospheric fading mitigation

Optical Link

Optical Link

Satellite T&C, Ranging

High Data Rate System (RF)



Table Mountain, CA



Hawaii

## Optical Ground Station 1

- 1 m transmit and receive aperture
- 10 W transmitter

## Optical Ground Station 2

- 60 cm receive aperture
- 15 cm transmit aperture
- 10 W transmitter

STPSat-6 Antenna and Ground Equip. (SAGE)

Space Network/WSC

LMOC Extension

GSFC

LCRD Mission Ops Center (LMOC)

White Sands, NM

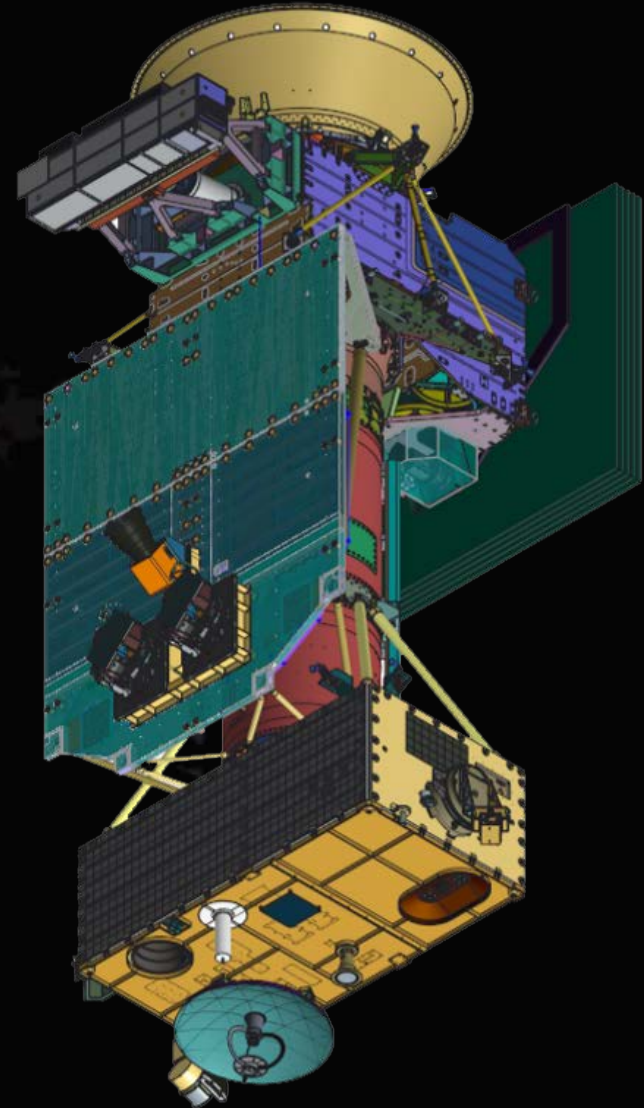
STPSat-6 Satellite Ops Center (SSOC)

Space Network/WSC

# LCRD Spacecraft Host



- Original LCRD plan (through PDR) was to be a hosted payload on a Space Systems Loral spacecraft
- LCRD found a partner opportunity and will fly on the Space Test Program Satellite (STPSat-6) mission.
  - The Space Test Program mission is scheduled to launch in 2019.
  - LCRD will continue to fly hardware and operate to allow demonstration of commercially hosted payload concepts.





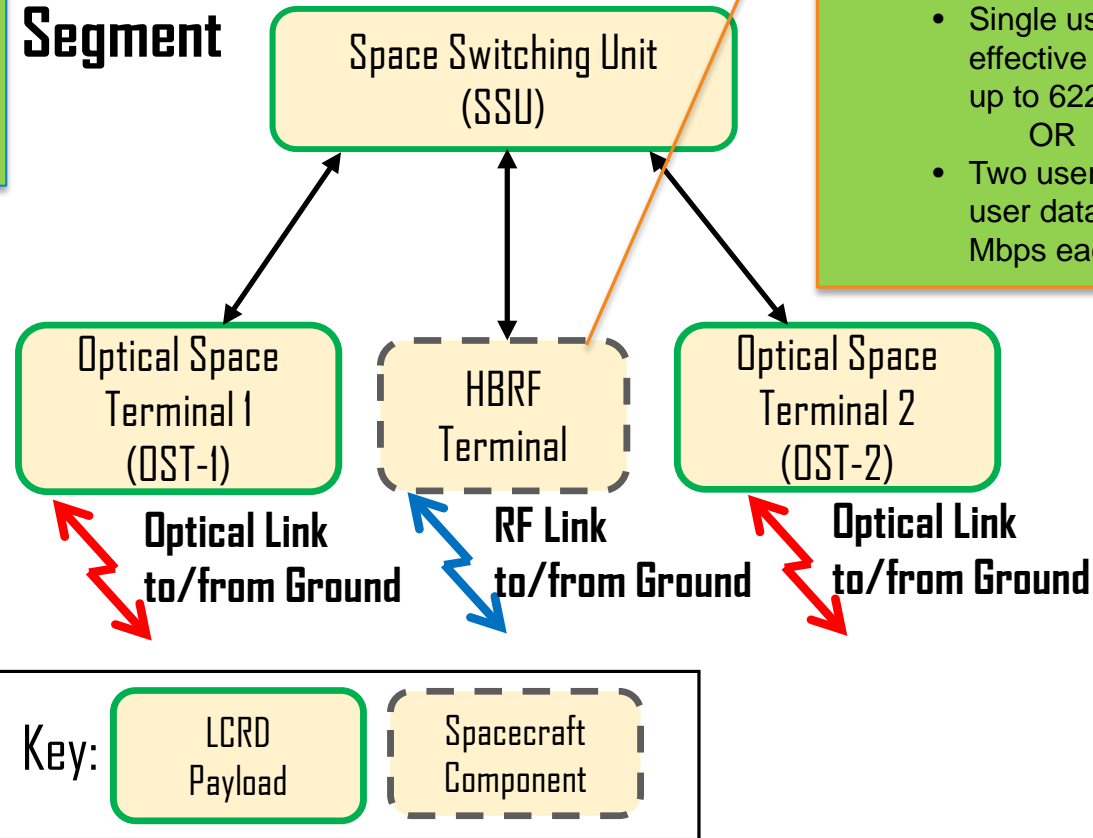
# Added High-Bandwidth RF



## Original Design:

- Two optical space terminals
- Two optical ground stations, each capable of supporting a relay trunkline or simulating a user
- Trunkline carrying same bandwidth as link between relay and user
- Switching will be performed on the LCRD payload on a frame-by-frame basis.

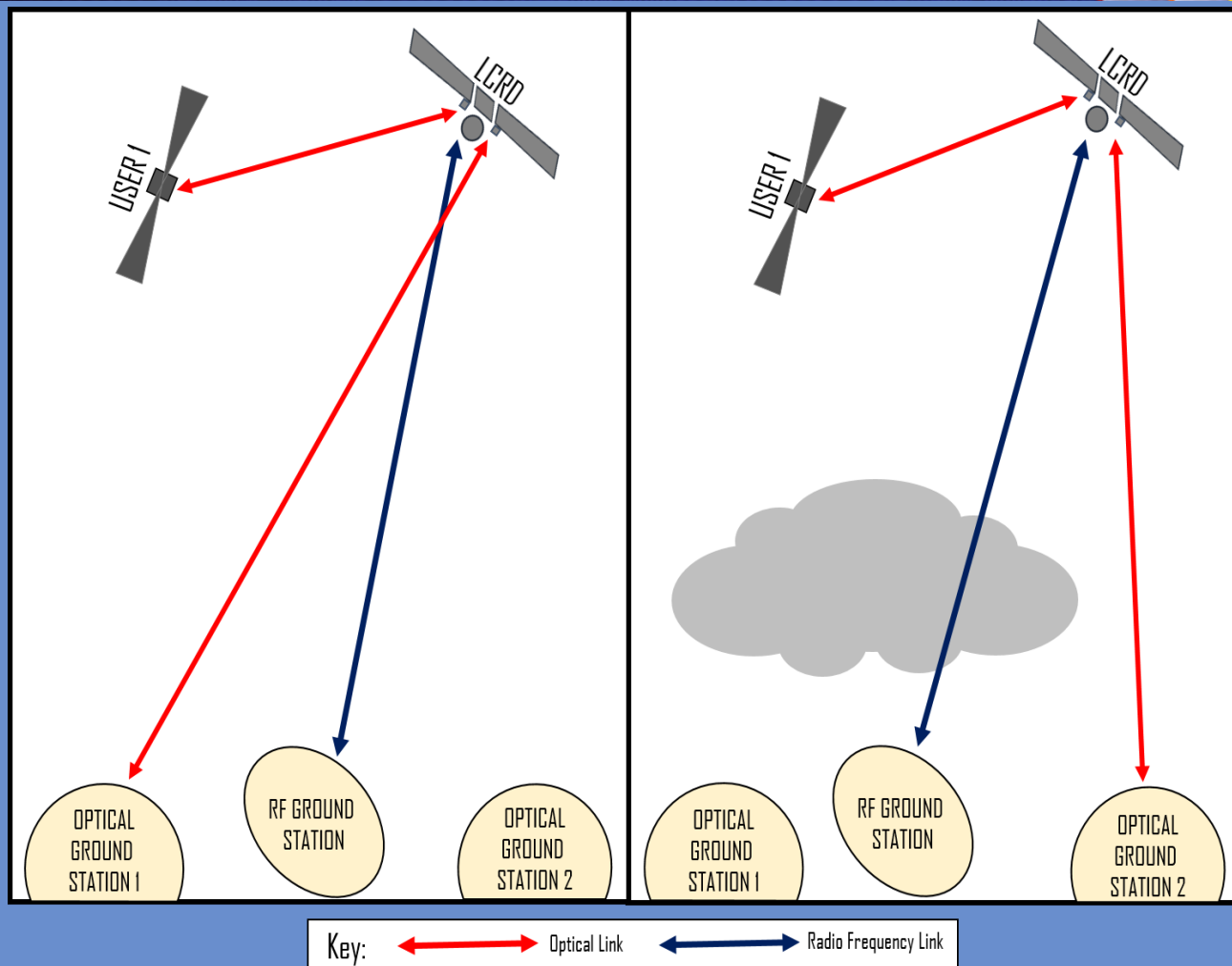
## LCRD Flight Segment



## Added High-Bandwidth RF:

- Forward Link: One or two users with an effective user data rate up to 32 Mbps for each user
- Return Link:
  - Single user with an effective user data rate up to 622 Mbps OR
  - Two users with effective user data rates up to 311 Mbps each

# Optical/RF Trunkline Combination



- RF meets requirements for real-time or very low-latency delivery (such as commanding, telemetry, science alerts, voice, video, etc.), but is constrained in terms of bandwidth.
- Optical meets higher bandwidth requirements but is susceptible to outages.
- LCRD will investigate various schemes for managing and scheduling data flows.

# STPSat-6 Spacecraft Operations Center at WSC



Spacecraft operations center and TT&C RF ground station at White Sands Complex

- Provides cost savings
- Allows NASA to gain insight into the operations of a spacecraft with an optical relay capability

Separation of the payload operations in the LMOC allows for the development of operations concepts that will not preclude future relay capabilities flying as hosted payloads

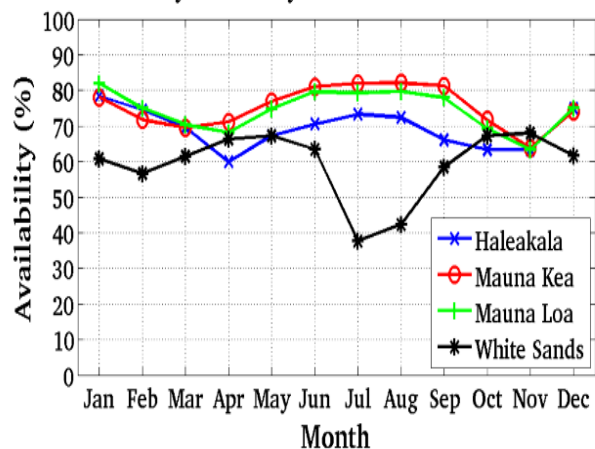


# OGS-2 in Hawaii



- The LCRD ground station was relocated from White Sands to Maui.
- The location has better cloud-free line-of-sight (CFLOS) statistics.
- OGS-1 remains at Optical Communications Telescope Laboratory (OCTL), Table Mountain, California.

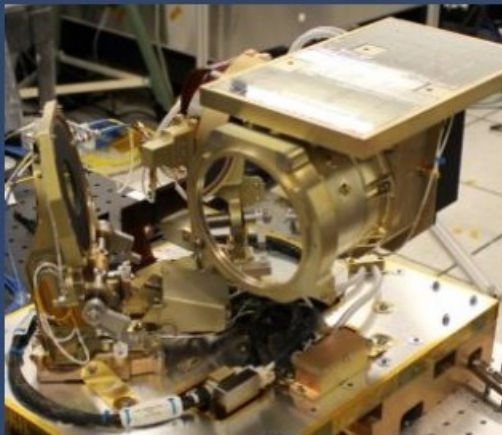
Mean Monthly Availability at Each Site with a GEO Satellite



# LCRD Flight Hardware Status



- LCRD flight hardware advancing toward completion
- Component environmental testing underway
- Payload delivery to spacecraft scheduled for June 2018



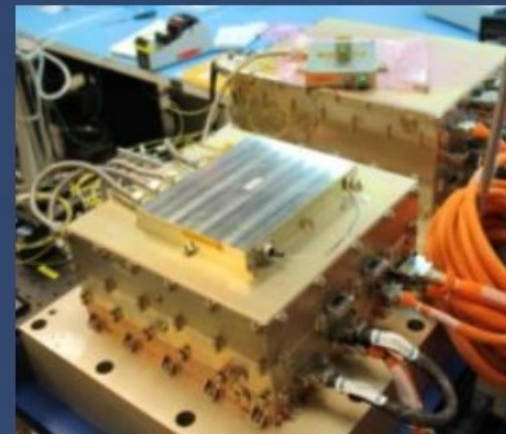
Optical Module



Controller Electronics



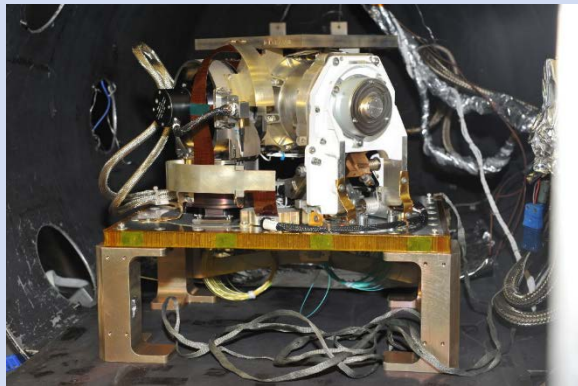
Modem



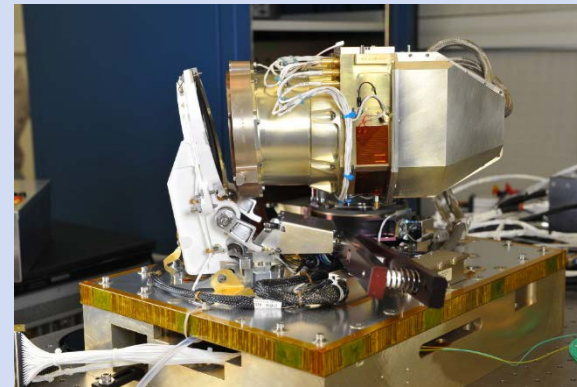
Switch



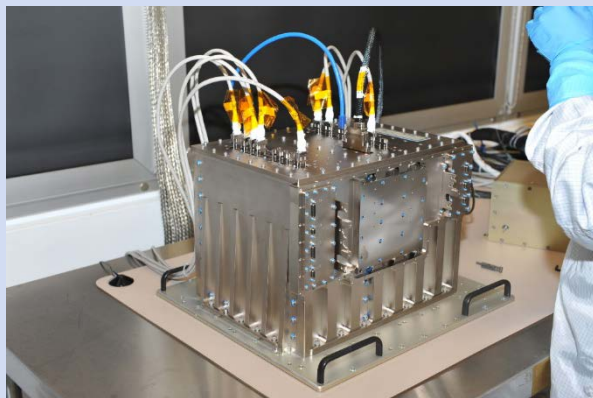
# LCRD Payload Progress



Optical Module #1  
Bake Out



Optical Module #2  
Latch Assembly

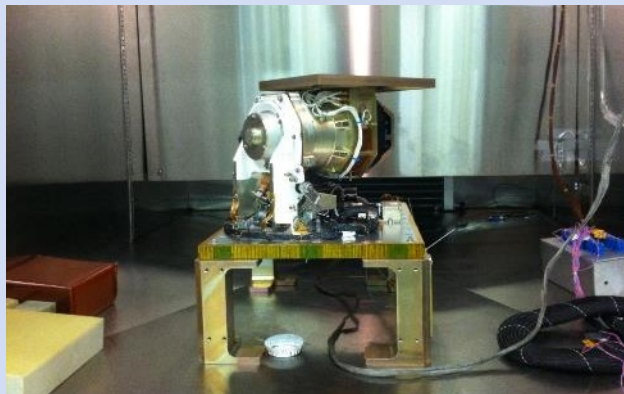


SSU  
SHIM to SSU Fit Check



Modem 2  
Fiber Optical Assembly of High-Speed Slice

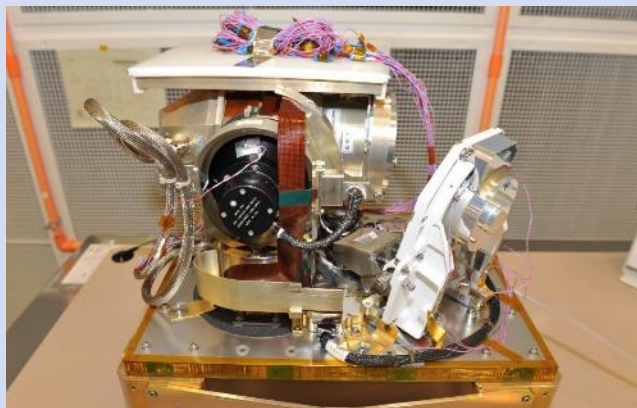
# LCRD Payload Progress (cont.)



Bake Out of Optical Module #2



B29 Clean Room  
Pass-thru security panels are now installed.



Optical Module #1  
Pre-blanket overview in preparation  
for TVAC test



Fit-check of Modems  
Tower A and Tower B to lifting fixture

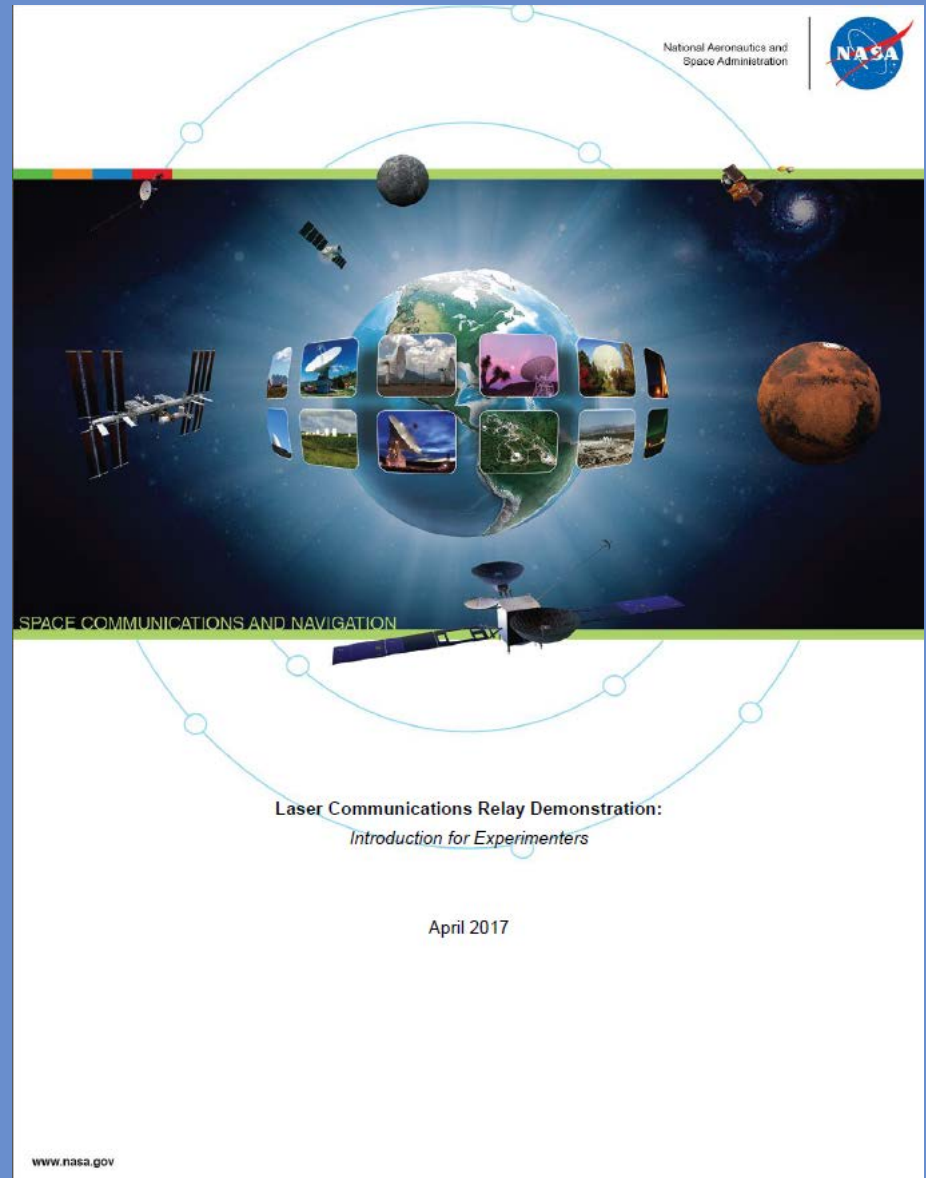


# LCRD Flight Modem Vibration Testing



# LCRD Experiments

- **Experiments will begin immediately following launch and payload checkout.**
- **The highest priority experiments will demonstrate technology readiness for the next-generation relay capability.**
  - Laser communications link and atmospheric characterization
  - Relay operations
  - Optical-based networking services
- **Other experiments include:**
  - Development of operations efficiency (handover strategies, more autonomous ops, etc.)
  - Planetary/Near-Earth relay scenarios (additional delays, reduced data rates, non-continuous trunkline visibility)
  - Low Earth Orbit (LEO), real or simulated
  - User-to-user relay
  - Direct uplink/downlink
  - Commercial applications
- **LCRD Introduction for Experimenters document will describe possible experiments and process for experiment solicitation.**

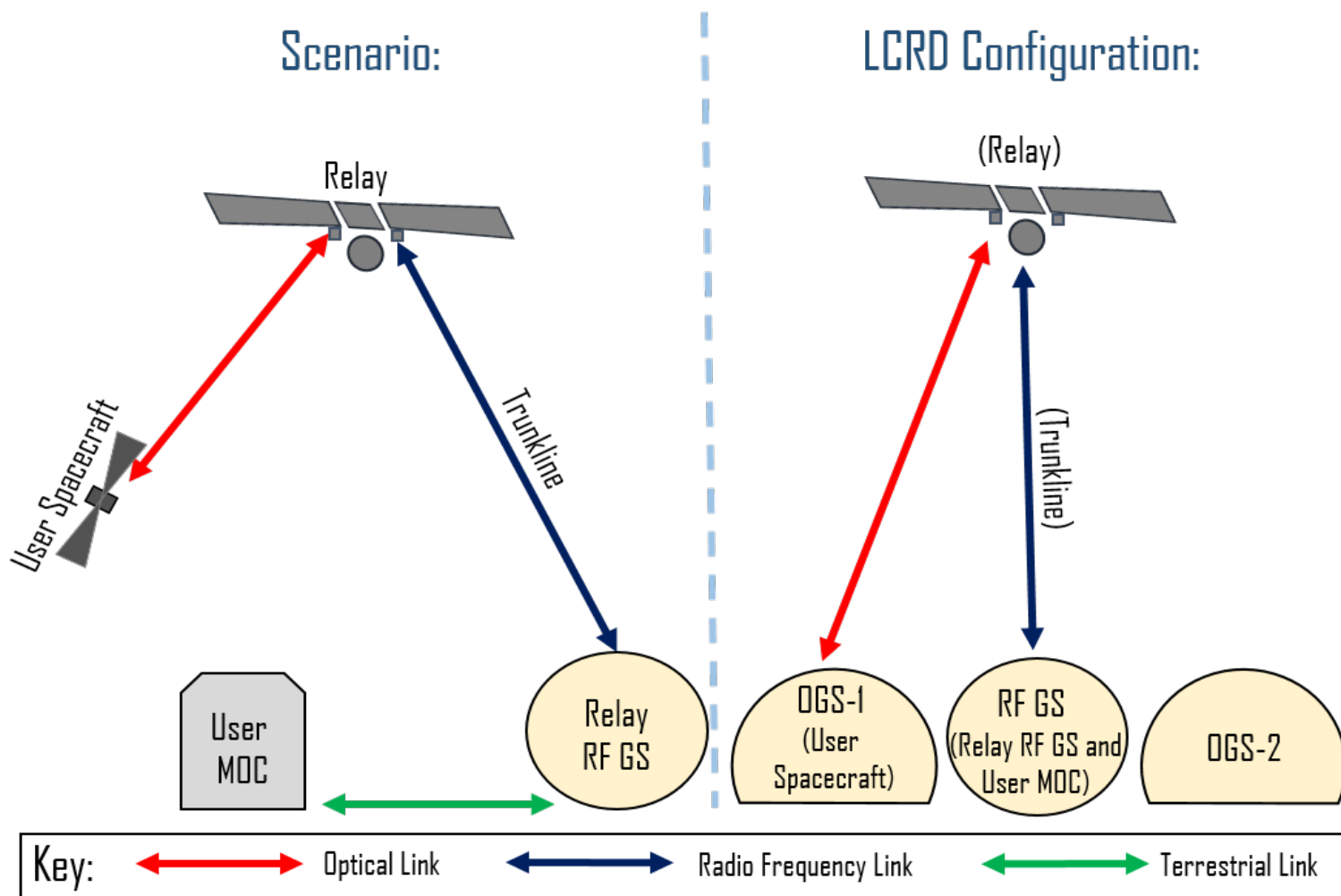




# LCRD Experiment Configuration



## Relay Provider for Single User



# Anticipated LCRD Products



- Understanding of necessary requirements for future NASA systems
  - Resolution of Future System TBD/TBRs
  - Data for trade studies
  - Optimized operational procedures
- Demonstration of ability to procure, integrate, test and operate space optical communications hardware
- Demonstration of NASA development of optical communications systems based on Massachusetts Institute of Technology Lincoln Laboratory (MIT LL) designs
- Optical communications ground systems and network operations center development and ops experience
- Atmospheric measurements and model development
- Link performance measurements and model development
- Flight hardware performance characterization and flight hours
- Demonstration of optical communications benefits for a variety of mission scenarios



# PATH TO OPTICAL RELAY OPERATIONS



# NASA's Future High-Rate Communication Services



Ka-band RF  
downlink and  
uplink

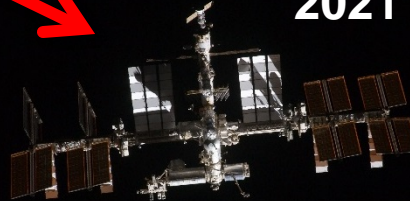
**2019**



LCRD with two optical  
heads in GEO

2.23 Gbps return link  
51 Mbps forward link

**2021**



High bandwidth  
optical downlink  
option >95%  
availability

**WSC**

311 Mbps PPM return  
20 Mbps forward link

**2021**

Orion EM-2 at  
cis-lunar orbit

> 100 Gbps from  
LEO in 1.8U volume

**2018**

Mission users in LEO with  
high data volumes: total  
return: > 56 Tb/day

Four optical ground stations with PPM  
support and A-O or Coherent Combining

**CONUS**

**LMOC**

**LVMR**

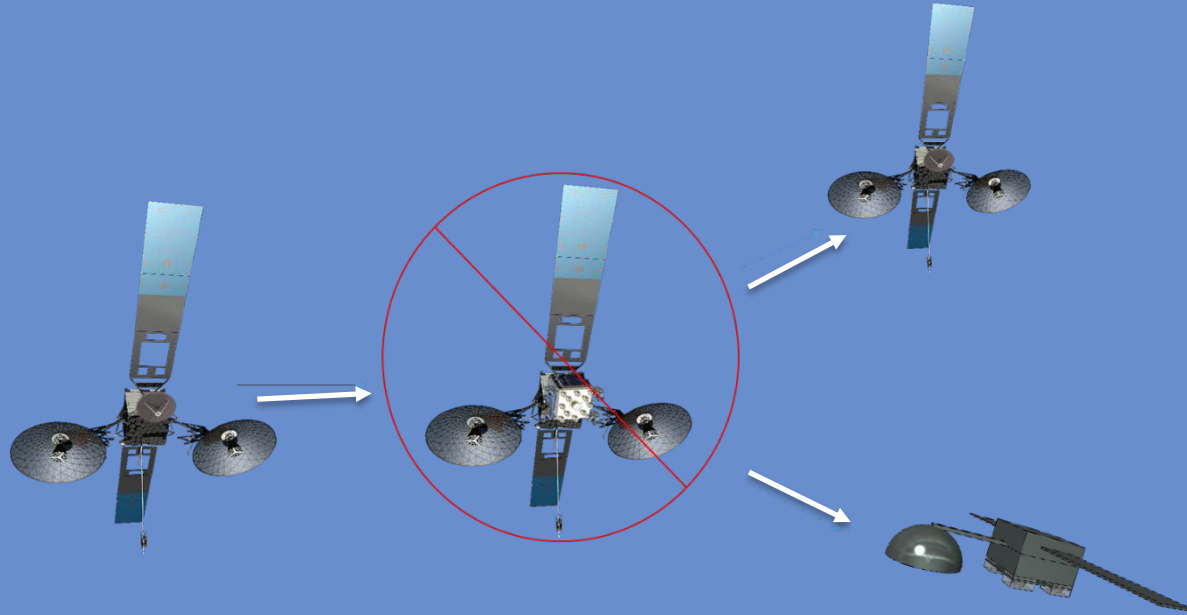
**JPL TMF**

**PI Site**

**Hawaii**



# Disaggregated Services Approach



The current Earth relay architecture incorporates all services on copies of a single dedicated spacecraft (TDRS).

The next-generation architecture under consideration disaggregates the services between multiple spacecraft:

- Optical services separate from RF services
- Nodes dedicated to either spacecraft or hosted payloads
- Some services potentially provided by commercial or industry partners

Benefits include:

- Independent replenishment of existing service capabilities
- Deployment of new services based on requirements and technology development

# Summary



- LCRD is NASA's next step toward an operational optical relay service capability.
  - LCRD will support experiments for two years following launch in June 2019.
  - The addition of HBRF system and redundant onboard data switch increases likelihood of an extended mission to include early operational support.
- An optical relay capability is being targeted for a 2025 launch as the first node of the next generation relay architecture.
  - Early studies and technology development are underway.